IR302-FQ33-

WINDAR PHOTONICS

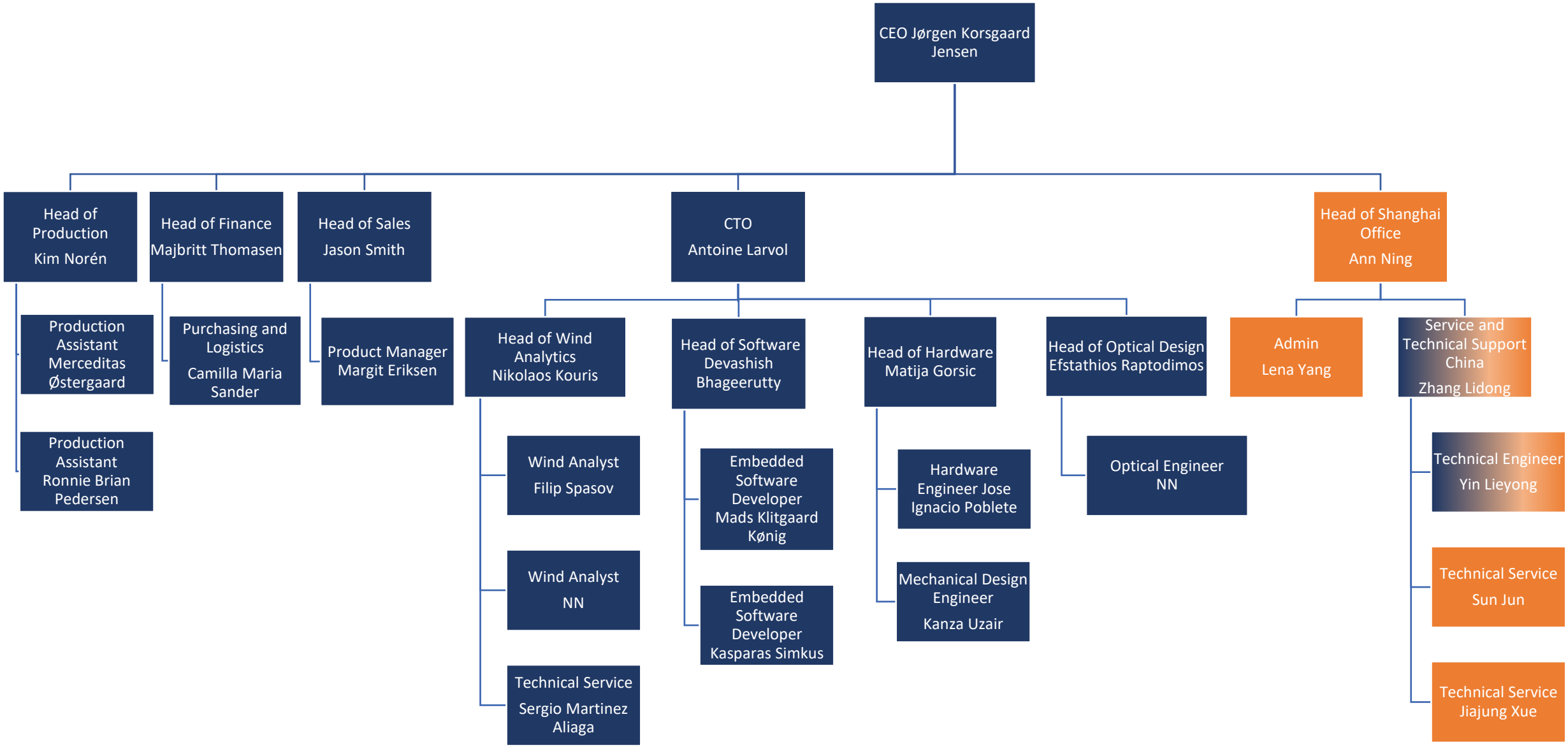
OVERVIEW

Developer of durable, high quality cost-effective LiDAR products which increase the efficiency and revenues of wind energy projects

- Pioneer of applying and promoting LiDAR sensors for turbine optimisation to the wind industry
- Retrofit market total potential market – up to 300,000 units
- OEM total market potential – 20-25,000 units pa

Short term – strategic sales focus:

- Retro-fit market segment North America, Europe and Japan focused on specific turbine platforms
- Selected existing customer relationships in China


CEO Jørgen Korsgaard Jensen
Head of Production
Kim Norén
Head of Finance
Majbritt Thomasen
Head of Sales
Jason Smith
CTO
Antoine Larvol
Head of Shanghai Office
Ann Ning
Production Assistant
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Production Assistant
Ronnie Brian Pedersen
Purchasing and Logistics
Camilla Maria Sander
Product Manager
Margit Eriksen
Head of Wind Analytics
Nikolaos Kouris
Head of Software
Devashish Bhageerutty
Head of Hardware
Matija Gorsic
Head of Optical Design
Efstathios Raptodimos
Admin
Lena Yang
Service and Technical Support China
Zhang Lidong
Wind Analyst
Filip Spasov
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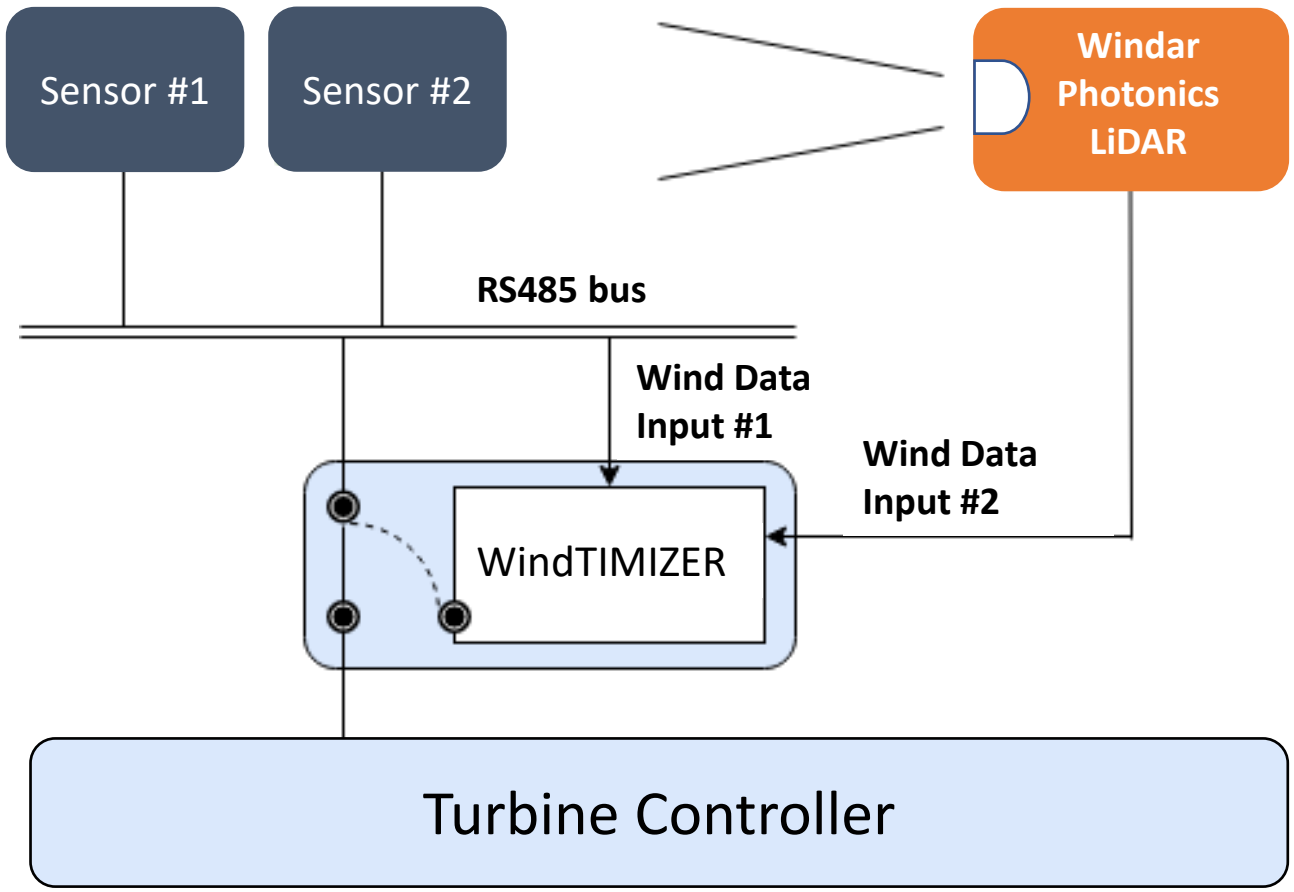
NN
Technical Service
Sergio Martinez Aliaga
Embedded Software Developer
Mads Klitgaard Kønig
Embedded Software Developer
Kasparas Simkus
Hardware Engineer
Jose Ignacio Poblete
Mechanical Design Engineer
Kanza Uzair
Optical Engineer
NN
Technical Engineer
Yin Lieyong
Technical Service
Sun Jun
Technical Service
Jiajung Xue

Features:

- Laser unit integrated with the Optical Head
- Portable Design
- Increased Durability
- Better performance in elevated nacelle temperatures.
- Increased data availability.

Windar Services:
Dynamic Yaw Realignment

Dynamic Yaw Control - **WindTIMIZER**



To enable the dynamic yaw correction feature of the WindEYE™, the LiDAR needs to be integrated with the wind turbine control system.

The WindTIMIZER is a mediator that allows the LiDAR to integrate with the wind turbine control system and the legacy anemometry as part of a retrofit solution.

As such, the WindTIMIZER functions as a mediator between the controller and the WindEYE™ system without the necessity of actually altering anything in the wind turbine controller at all.

Operational achievements:

- **3% power increase verified by Windar and the turbine OEM**
- **Wind bin-based alignment system to reduce loads especially during high wind speed periods (potential down time not included in the power increase verification)**
- **Transfer function verification**

Other operational benefits:

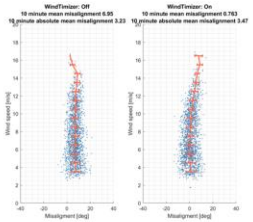
- On-line access to operational wind data
- Real time turbulence intensity data available – primarily verifying wake sector management
- NEW feature (January 2022) rotor imbalance detection

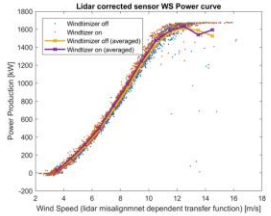
Example from verification report:

Summary of 07K04 results:

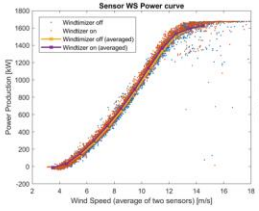
1. Misalignment:
   - WT off: 7 deg
   - WT on: 0.8 deg
2. Yaw activity:
   - WT off: 16.2 deg/hour
   - WT on: 16.4 deg/hour
3. AEP gain:
   - With Lidar corrected wind speed : 3.3 % based on:
     - 11.9 days of turbine operation / Toggle: On
     - 11.86 days of turbine operation/ Toggle: Off
   - With sensor wind speed : 3.4% based on:
     - 24.35 days of turbine operation/ Toggle: On
     - 24.43 days of turbine operation/ Toggle: Off

Turbine 07K04 – Windar 1226





Power Curve with lidar corrected wind speed



Power Curve with sensor wind speed (Scada)

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For detailed project verification – see seperate Verification reports from Windar and the OEM

Additional Servies – Retro-fit market:

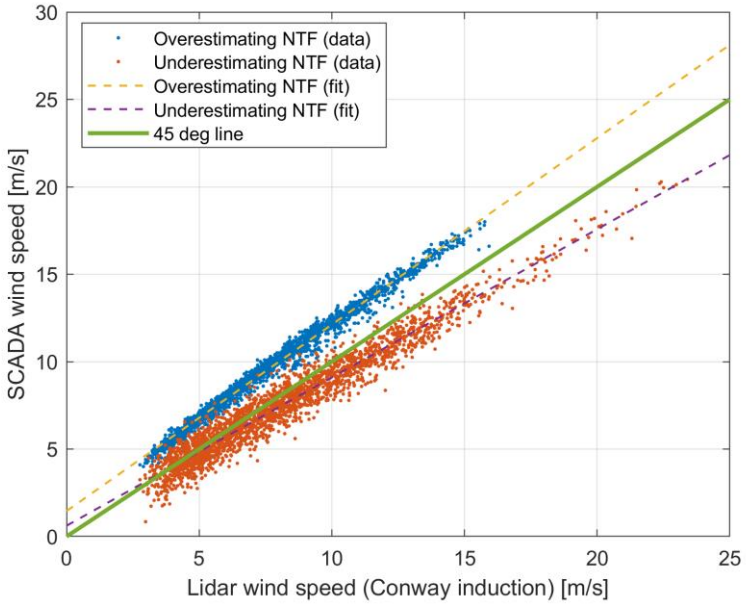
- Nacelle transfer function evaluation
- Wake Analysis
- Rotor Imbalance Detection

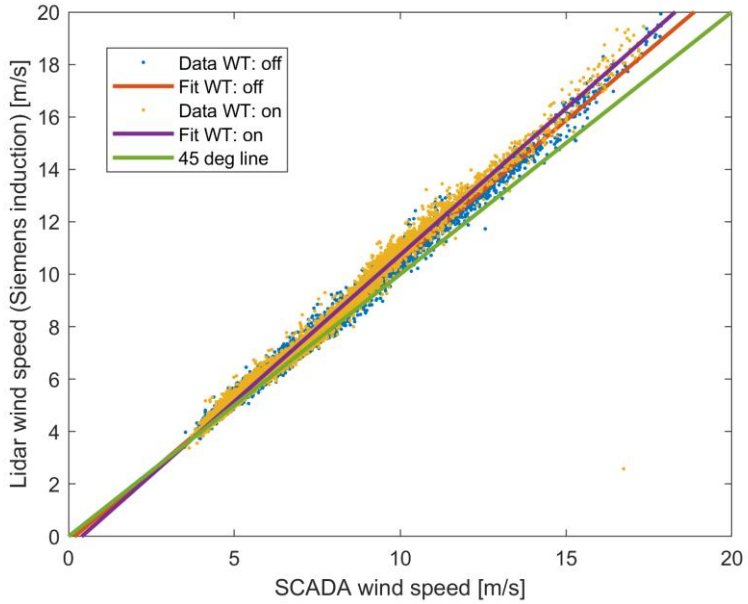
Nacelle transfer function:

Nacelle Transfer Function (NTF) is applied to the nacelle anemometry signals
to account for the influence of turbine's rotor and nacelle on the wind speed measurements. It represents the relationship between the free ow speed and the wind
speed captured by the nacelle sensors.

- **Overestimating NTF** will lead to production losses caused by earlier cut out of the turbine.
- **Underestimating NTF** will lead to turbine operation above specification, increasing maintenance & potentially damaging the turbine

Nacelle transfer function evaluation





Examples of overestimating(blue) & understimating(orange) NTF, taken from Windar campaigns in 2020-2021.

NTF evaluation	Cut-in (specification-real) [m/s]	Cut-out (specification-real) [m/s]	Result
Overestimating wind speed	4 - 2.5	25 - 21.9	AEP Loss 1.5 %
Underestimating wind speed	4 - 4.3	25 - 27.4	Increased loads

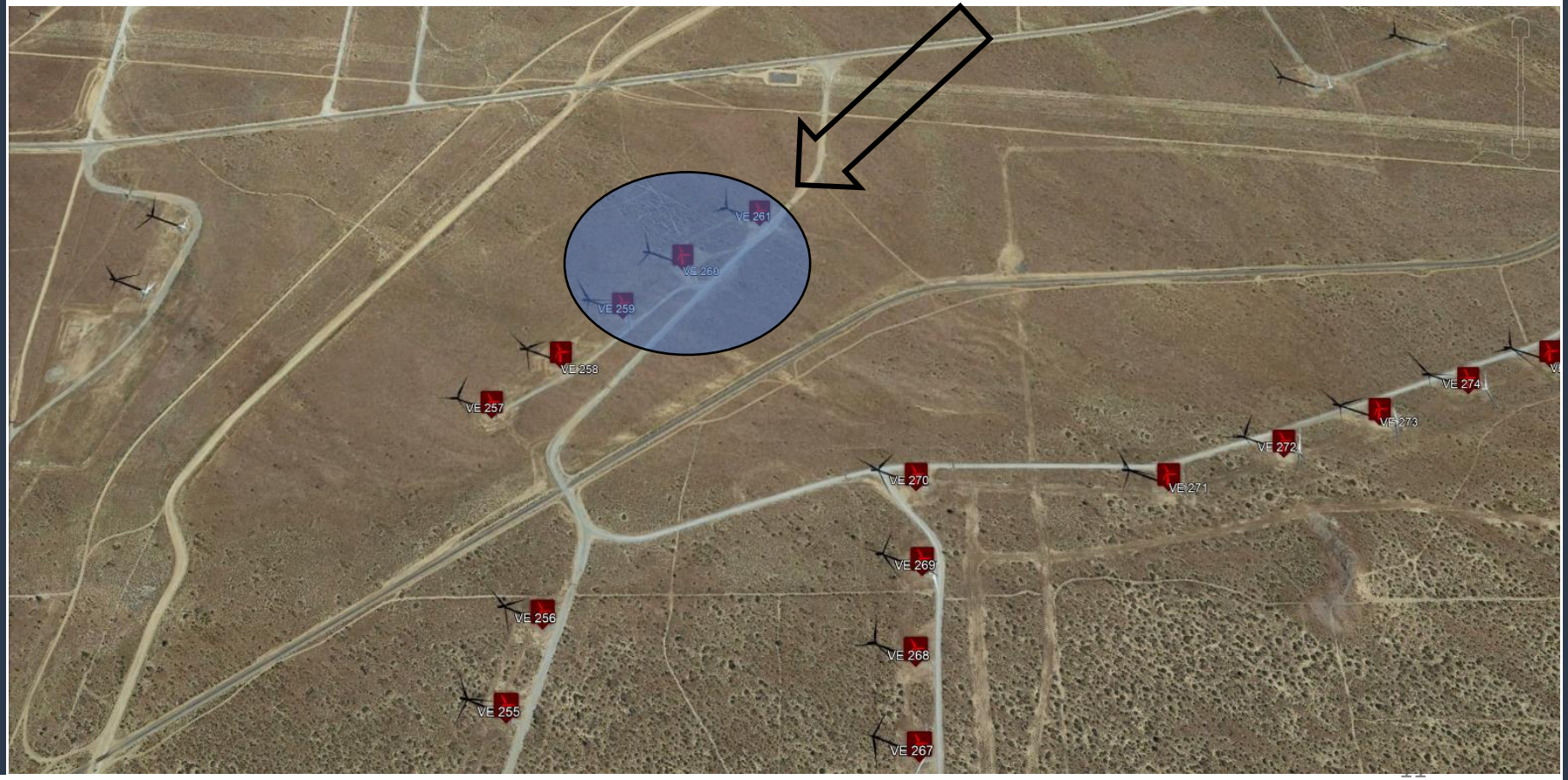
Expected outcome of inaccurate transfer function.

Windar Services:
Wake Analysis

Wake sector management
Cluster: T261/T260/T259, NorthEast sector (10-90 deg)

Sector Management (NE sector):

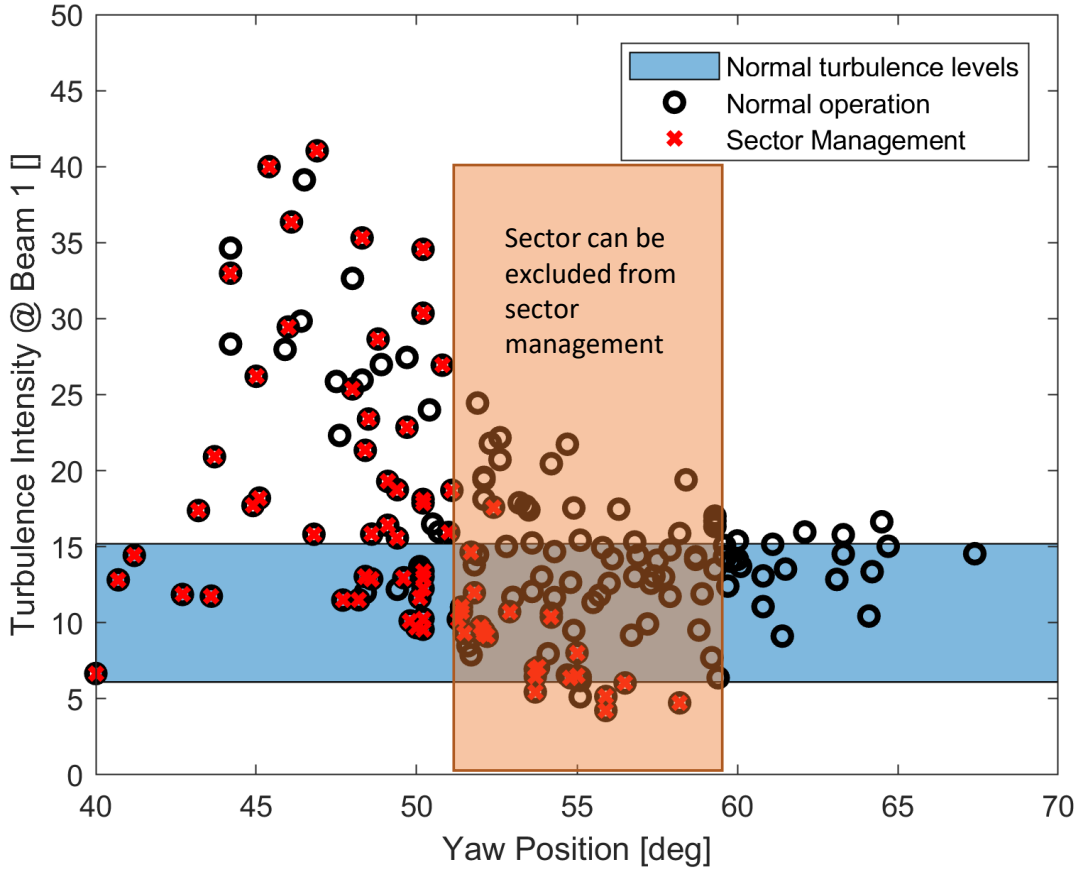
1. Turbine 261: **95h/year** under sector management. The turbine is not affected by wake at this sector, thus sector managed unnecessarily. The sector mangement applies for wind speeds larger than 10 m/s.
2. Turbine 260: **23h/year** under sector management. 99 % of this time the upstream turbine (T261) is not operating due to sector management, thus turbine 260 is sector managed unnecessarily for **22.7h /year**
3. Turbine 259: 23h/year under sector management. 97 % of this time the upstream turbine (T260 & T259) is not operating due to sector management, thus turbine 260 is sector managed unnecessarily for **22.4h /year**
4. The sector management on the NE sector leads to unnecessary losses of **150 MWh/year.**



Wake sector management
Turbulence levels evaluation

Windar Wake Analysis:

1. Wake sectors can be optimized based on true turbulence measurements
2. With the True North Verification, unnecessary derating due to the Nacelle position measurement error can be avoided.



Windar Services:
Rotor Imbalance Detection

Rotor Imbalance – Pitch Misalignment

Rotor Imbalance:

1. Pitch misalignment results in significant power losses
2. Extreme increase in yaw bearing moment.
3. Detection and correction of pitch misalignment would lead to significant power gains & load reduction.

Currently developing a method to identify rotor imbalance using WindEYE sensors.